MOTOR VEHICLE EQUIPPED WITH A DIESEL PROPULSION ENGINE

[1] This invention concerns a motor vehicle equipped with a diesel propulsion engine, the exhaust system of which includes a discontinuously regenerating exhaust gas purification system which comprises a catalytic converter unit that burns diesel fuel catalytically. Continuously regenerating exhaust gas purification systems of this kind may specifically comprise diesel particulate filters and NO_x accumulating catalytic converters.

[2] To comply with environmental specifications the exhaust gases of motor vehicles propelled by combustion engines are subjected to a purification process. Specifically, appropriate particulate filters are utilized to reduce the particulate emission of the exhaust gases of motor vehicles propelled by diesel engines. Such particulate filters need to be periodically regenerated by burning off the particles accumulated on the filter surface. Due to the relatively low exhaust gas temperatures of modern diesel engines, to initiate regeneration, the exhaust gas temperature must be raised using appropriate measures or devices if filter regeneration is to be feasible in conditions other than full load operation, even when using fuel additives that are capable of lowering the particulate ignition temperature which without such additives and depending on the soot composition, ranges between 470° C and 600° C, by approximately 100° C, but which in the long run cause the particulate filter to clog, necessitating its cleaning.

[3] For this purpose various burners (refer to DE 19504183 A1 and DE 19717544 A1) have been proposed for installation upstream of the particulate filter. On the negative side however, there are a considerable structural and financial effort, the considerably increased space required for installation due to the integration of the comparatively large burner into the exhaust system, and the detrimental effect on the flow conditions within the exhaust pipe, due to the burner.

[4] One solution that regarding some of the above mentioned aspects is more favorable, has been proposed in EP 132166 A1, in which a low-boiling, organic fluid evaporates on a glow plug that extends into the exhaust gas carrying component connected upstream of the particulate filter, where the vapors ignite either after their mixing with the oxidic exhaust gas at the tip of the glow plug or – without ignition – are mixed with the stream of exhaust gases. In the latter case a temperature increase of the exhaust gases ducted to the particulate filter is caused by catalytic oxidation of the vapors of the low boiling organic fluid in a catalytically coated area of the particulate filter. A particular disadvantage of this is the engineering and logistic effort concerning the storage of the low boiling organic fluid. Furthermore, the regeneration of the

diesel particulate filter utilizing this heating device calls for exhaust gas temperatures of above 450° C which in modern diesel engines can only be attained under full load.

[5] DE 3139565 A1, from which a motor vehicle of the generic kind may be derived, describes the injection of diesel fuel using atomizer nozzles in, or immediately ahead of, a catalytically coated area of a particulate filter, to increase the exhaust gas temperature in this manner by means of catalytic oxidation of the fuel. An electrical heating element is imbedded in the catalytically coated area of the particulate filter to initiate catalytic oxidation. Specific disadvantages of the system known from DE 3139565 A1 are, aside from the considerable non-homogeneity of the temperature distribution, the fact that the atomized fuel absorbs heat from the exhaust gas stream through a partial evaporation, and that the atomizer nozzles – given the conditions prevailing in non-purified exhaust gases – tend to clog, thereby rendering the affected heating device non-functional within a short period of time; this explains why systems based on DE 3139565 A1 never went into production.

[6] Finally, attempts have been made to increase the exhaust gas temperature to the ignition temperature of the soot collected on the particulate filter, using electrical heating elements; such attempts were however, quickly aborted as the required electrical power was not able to be provided in conventional motor vehicles.

[7] NO_x accumulating catalytic converters are increasingly used to reduce the emission of nitrogen oxides. Regeneration of the former requires an enrichment of the exhaust gases. While this is not a problem with gasoline engines, diesel engines that are operating with excess air and whose exhaust gases therefore as a rule also contain excess air, require special measures to be taken.

[8] In the light of the state of the art explained above, the object of this invention is to create a motor vehicle of the type referenced earlier, equipped with an exhaust system that includes a discontinuously regenerating exhaust gas purification system whose subassemblies required for the regenerating mode of the exhaust gas purification system are technically simple and low-cost, require only a minimum of additional installation space and are low-maintenance and highly reliable.

[9] According to the above invention the object has been accomplished using the following design features:

- the catalytic converter unit has an upstream fuel evaporator unit connected to it;

- the fuel evaporator unit comprises an electrical heating element and is connected to the vehicle fuel tank by a fuel line;
- the fuel evaporator unit is installed with spatial separation from exhaust gas carrying components;
- a fuel vapor feeding channel extends between the fuel evaporator unit and an exhaust gas carrying component and, upstream of the catalytic converter unit, discharges into an exhaust gas carrying component.

[10] One essential feature of the motor vehicle based on this invention which in combination with other features characteristic of this invention, contributes in a special way to the accomplishment of this task, is the installation of the fuel evaporator unit comprising an electrical heating element, in spatial separation from the exhaust gas carrying components. This specifically implies that the fuel evaporator unit does not extend into any of the exhaust gas carrying components upstream from the catalytic converter unit. The spatial separation of the fuel evaporator unit from exhaust gas carrying components, and the feeding of the fuel vapors provided by the fuel evaporator unit into the exhaust pipe upstream of the catalytic converter unit through a fuel vapor feeding channel, prevent the fuel evaporator unit from being exposed to the considerably fluctuating exhaust gas temperatures during vehicle operation. In this manner the environmental conditions in which the fuel evaporator unit is expected to deliver fuel vapors, are easier to monitor and control. This in turn allows the functional optimization of the fuel evaporator unit comprising an electrical heating element, to make it suitable for the evaporation of diesel fuel with consistently favorable results. Furthermore, the supply of fuel vapors delivered into the exhaust pipe by the fuel evaporator unit using a fuel vapor feeding channel, results in less interference with the flow conditions within the exhaust pipe than using conventional burners, and clearly in an increased degree of flexibility regarding the spatial arrangement and/or packaging of the fuel evaporator unit; for modern vehicles occasionally having extremely tight installation conditions for the exhaust system, the latter is of particular advantage.

[11] Strictly for clarification it may be stressed that it is the fuel evaporator unit alone where a physical process occurs, as it is here where the state of matter of the diesel fuel changes from the liquid to the vapor state; there is however no chemical change of the diesel fuel taking place, such as reformation or the like.

[12] The system explained above and implemented in motor vehicles based on this invention, may be especially utilized for the regeneration of a particulate filter as well as for the regeneration of a NO_x accumulating catalytic converter, or for the regeneration of a combined exhaust gas purification device. In the former case the entire amount of fuel vapors generated by the fuel evaporator unit is ducted into the exhaust gas stream upstream from an oxidizing catalytic converter which is connected upstream of the diesel particulate filter, during which, depending on the specific operating point of the engine, an appropriate amount of fuel is evaporated and subsequently catalytically burned in the oxidizing catalytic converter to ensure that the temperature of the exhaust gases downstream of the oxidizing catalytic converter is sufficient for the regeneration of the downstream particulate filter. If however the system based on this invention is utilized for the regeneration of an NO_x accumulating catalytic converter, then the fuel vapors generated by the fuel evaporator unit are used to enrich the exhaust gases ducted to the NO_x accumulating catalytic converter.

[13] In combination systems the spatial separation of the fuel evaporator unit from exhaust gas carrying components can be utilized with particular advantage, as it takes only a single fuel evaporator unit to produce the fuel vapors for the regeneration of the particulate filter and the NO_x accumulating catalytic converter.

[14] One initial, preferred further development of this invention is characterized in that the fuel vapor feeding channel discharges into a cross-sectional reduction of the specific exhaust gas carrying component configured as a venturi nozzle. The resulting pressure drop in the fuel vapor feeding channel and the fuel evaporator unit, promotes the evaporation of the diesel fuel and, by means of appropriate lowering of the boiling range, contributes to the reduction of electrical energy consumed for the evaporation.

[15] Another preferred further development of this invention provides that the fuel evaporator unit comprises an upright glow plug which, while maintaining an annular gap, is surrounded by a jacket tube into which both the fuel line and the fuel vapor feeding channel enter. The upright arrangement of the glow plug promotes a particularly homogenous evaporation of the diesel fuel fed into the annular gap defined to be between the glow plug and the jacket tube. A particularly favorable evaporation characteristic is obtained when the internal diameter of the referenced annular gap is between 0.6 mm and 2 mm. With such a dimensioning and with respect to the

evaporation results, optimum conditions are obtained for the individual key factors such as heat transfer, dripping due to boiling, capillary effects and the like.

[16] It was found to be particularly adventageous to have a spiral guide element installed in the annular gap located between the glow plug and the jacket tube. This serves to guide the heated and boiling fuel and, subsequently, the fuel vapors in a spiral path around the glow plug so that firstly any localized temperature differences on the surface of the glow plug can be evened out and that, due to the respective, extended flow path, an homogenizing effect for the prepared fuel vapors is obtained. Furthermore, due to the spin flow, any developing fuel drippings are exposed to centrifugal forces that promote their condensation on the jacket tube, so that in particularly compact fuel evaporator units the risk of fuel drippings getting into the exhaust gas stream is very low. This risk can be further reduced by having the fuel vapor feeding channel's end facing the fuel evaporator unit, extend into the jacket tube above the glow plug. This is because in this situation there is a cyclonic function of the unit consisting of the fuel evaporator unit and the fuel vapor feeding channel, to the effect that the fuel vapors drawn from the fuel evaporator unit are free of any fuel drippings that, driven by centrifugal force, would drift radially outward in the direction of the jacket tube.

[17] Another further development of this invention is distinguished by the fact that the jacket tube is encompassed by an insulator. Aiming at further optimization of the evaporation process, this allows the environment in which the evaporator unit operates to be evened out further.

[18] Regarding dimensioning of the fuel vapor feeding channel, the particularly preferable ratio of the fuel vapor feeding channel cross-section to the cross-section of the exhaust gas carrying component in the area of the fuel vapor feeding channel outlet, is between 0.006 and 0.015. This ratio proves to be particularly favorable with regard to a sufficiently good mixture of fuel vapors fed into the exhaust gas stream, without interfering with the flow conditions in the exhaust pipe when not in the regenerating mode.

[19] The amount of fuel vapors required for the regenerating mode depends on the individually different conditions. If due to the specific structural conditions a particularly large amount of fuel vapors is to be provided to initiate the regeneration of the particulate filter and/or the NO_x accumulating catalytic converter by the fuel evaporator unit within a short period of time – especially taking into account the capacity of the electrical system of the particular vehicle – it may prove to be advantageous to connect a preheating stage upstream of the fuel

evaporator unit, in which fuel is preheated. Specifically, such a preheating stage may comprise an intermediate accumulator in which the amount of fuel required for a one-time regeneration of the particulate filter may be temporarily stored and, using a suitable preheating element especially in the form of an electrical resistor-type heating element, preheated to a temperature level which is slightly below the boiling temperature. Gradual preheating of the fuel over a longer period of time, i.e., during the interval between two regeneration runs, helps the capacity of the electrical system in conventional motor vehicles. In addition, or alternatively, to an electrical heating element the preheating stage may also comprise a heat exchanger installed in the exhaust gas stream, in which the fuel that later-on is to be evaporated in the fuel evaporator unit, is heated utilizing the heat of the exhaust gases.

[20] Viewed against a comparable background, according to yet another preferred further development of this invention, it may be useful to evaporate and store on-demand the amount of fuel required for the regeneration of the diesel particulate filter already during the interval between two regeneration cycles. To this end the fuel evaporator unit appropriately comprises a pressure vessel with a heating device installed in it. The fuel vapors exiting the pressure vessel during regeneration may, especially for the benefit of its homogenization and/or additional heating, be ducted through a secondary heater as required. The above comments on preheating the fuel fed to the fuel evaporator unit in a preheating stage, apply here equally.

[21] If the invention is utilized for the regeneration of a particulate filter, according to yet another preferred further development of this invention, plans call for placing the oxidizing converter unit and the particulate filter in separate housings. This facilitates a particularly high reaction density in the oxidizing converter unit (which regarding its configuration is especially attuned to this function), resulting in a quick reaction and, consequently, a rapid initiation of the regeneration of the particulate filter, and a low fuel consumption. Besides, in this event, a more homogenous temperature distribution of the heated exhaust gases entering the particulate filter can be ascertained. Within the scope of this invention, however, installing the oxidizing converter unit and the particulate filter in separate housings is not at all a requirement. Under certain conditions, e.g., the installation conditions, it may rather be advantageous to place the oxidizing converter unit and the particulate filter in a common housing, specifically when the oxidizing converter unit is represented by a catalytically coated area of the particulate filter.

[22] Finally a yet another preferred further development of this invention is distinguished by a temperature sensor placed between the oxidizing converter unit and the particulate filter, where the temperature sensor communicates with a controller which in the regeneration mode controls the delivery rate of a fuel pump that feeds the fuel evaporator unit in dependence on the exhaust gas temperature measured upstream of the particulate filter. In this event, using an appropriate automatic variation of the fuel volume delivered to the fuel evaporator unit by the fuel pump, the specific engine operating point and the dependence of the exhaust gas temperature on this point can be taken into consideration with the result that by appropriate adaptation of the evaporated fuel volume the exhaust gas temperature may be controlled upstream of the particulate filter at a temperature value (e.g., 650° C) optimized for the regeneration of the particular filter.

[23] In the following this invention is explained in more detail using a few embodiments represented in the drawing. Shown are:

[24] Figure 1 the relevant partial section represented of an exhaust system built according to this invention, in a schematic view,

[25] Figure 2 a vertical section through the fuel evaporator unit utilized in the exhaust system shown in Figure 1,

[26] Figure 3 in a schematic view, a potential combination of the fuel evaporator unit shown in Figure 2 including a preheating stage and

[27] Figure 4 in a schematic view the potential configuration of the fuel evaporator unit for pre-evaporation.

[28] The partial section of an exhaust system represented in Figure 1 comprises a pre-tube 2 connectable to a manifold using a flange 1, a catalytic converter assembly 4 connected to the pre-tube 2 using a flange connection 3, having an oxidizing converter unit 6 located in a catalytic converter housing 5, and a filter assembly 8 connected to the catalytic converter assembly 4 using a flange connection 7, having a particulate filter 10 located in a particulate filter housing 9. Relatively close to the flange connection 3 the pre-tube 2 has a fuel evaporator unit 11 allocated which feeds evaporated diesel fuel into the exhaust gas stream flowing through the pre-tube 2.

[29] The fuel evaporator unit 11 is connected to the fuel tank 14 of the vehicle using a fuel line 12 which has a pump 13 integrated into it. Furthermore the fuel evaporator unit 11 is connected to the power source 16 of the vehicle using a switch 15. To this end the switch 15 is controlled in a generally known manner by a controller 17 which, analyzing several input

variables, especially the pressure drop across the particulate filter, initiates the regeneration process by closing the switch 15 and – with a defined time delay – starting the pump 13.

[30] The fuel evaporator unit 11 comprises an electrical heating element in the form of a glow plug 18 in an upright position. The electrical connector 19 has the electrical connecting cable 20 (ref. to Fig. 1) connected to it. The cylindrical glow pencil 21 of the glow plug 18 is encompassed by a jacket tube 23 maintaining an annular gap 22 with an internal width of 1 mm. On its face the jacket tube is hermetically closed by a lid 24 forming a vapor withdrawal space 26 generated by an appropriate gap between the lid 24 and the tip 25 of the glow pencil 21. Facing the base 27 of the glow plug 18 the jacket tube 23 is hermetically closed through the socket 28.

[31] The annular gap 22 contains a spiral guide element 29 which surrounds the glow pencil 21 in a spiral fashion. The fuel line 12 enters the jacket tube 23 adjacent to the base 27 of the glow plug 18.

[32] A fuel vapor feeding channel 30 in the shape of a small tube connects the fuel evaporator unit 11 with the pre-tube 2 and extends the end that is oriented toward the fuel evaporator unit 11 and configured as a fuel vapor withdrawal connector 31, into the vapor withdrawal space 26. The end of the fuel vapor feeding channel 30 oriented toward the pre-tube 2 extends into the pre-tube 2, specifically at the narrowest cross-section of a venturi insert 32 installed in the pre-tube 2.

The fuel evaporator unit 11 comprises an insulator 33 surrounding the jacket tube 23, which comprises an outer tube 34 and the insulating material 35 that fills the space between the jacket tube 23 and the outer tube 34.

[33] A temperature sensor 36 is located between the oxidizing converter unit 6 and the particulate filter 10. It captures the temperature of the exhaust gases upstream of the particulate filter; it uses a signal line 37 which in the regeneration mode communicates with the controller 17 to control the delivery rate of the fuel pump 13 that feeds the fuel evaporator unit 11, in dependence on the exhaust gas temperature measured upstream of the particulate filter 10.

[34] The explanation of this invention in the description segment allows the system represented in Figures 1 and 2 to be modified in a manner that makes the exhaust gas purification device to be regenerated no longer a matter of a particulate filter but rather a NO_x accumulating converter. Essentially, in this case the particulate filter including the upstream oxidizing converter is to be replaced by a NO_x accumulating converter.

[35] Figure 3 represents one possibility to connect a preheating stage 38 upstream of the fuel evaporator unit 11. In the embodiment shown in Figure 3 the preheating stage 38 comprises an intermediate accumulator 39 whose capacity is dimensioned to match the amount of fuel required for a one-time regeneration of the particulate filter. Using the pump 13, fuel is delivered to the intermediate accumulator 39 from the vehicle fuel tank. Within the intermediate accumulator 39 a preheating element 40 in the form of an electrical resistor-type heating element is installed. With its help the fuel absorbed by the intermediate accumulator is gradually heated resulting in its temperature at initiation of the regeneration process to be slightly below boiling temperature.

[36] A valve 42 is located in the flow channel 41 through which preheated fuel is delivered to the fuel evaporator unit 11 from the preheating stage 38, with the valve – like the pump 13 – being appropriately controlled by a controller to initiate or terminate the regeneration process.

[37] The intermediate accumulator 39 has the fuel feed connector 43 and the fuel discharge connector installed in such a manner that during regeneration of the particulate filter, mixing of the fuel that has replenished the intermediate accumulator with the fuel already preheated, is kept to a minimum to ensure that the latter is delivered to the fuel evaporator unit 11 at the highest possible temperature level.

[38] The contrivance represented in Figure 4 is capable of producing for "stockpiling", keeping available on-demand all the fuel vapors required for the regeneration of the particulate filter. To this end the fuel evaporator unit 11 comprises a pressure vessel 44 with an electrical heating device 45 located in it. Fuel drawn from the fuel tank of the vehicle is delivered to the pressure vessel by the pump 13 through a valve 46. An additional valve 47 is connected downstream from the pressure vessel 44. Utilizing the heating device 45 accordingly, the fuel fed into the pressure vessel 44 is gradually evaporated. The generated vapors 48 are stockpiled in the pressure vessel 44 until regeneration is initiated.

[39] When the valve 47 is opened to initiate the regeneration of the particulate filter, the previously prepared fuel vapors 48 flow into the pre-tube 2 through the fuel vapor feeding channel 30. The fuel vapor feeding channel has a secondary heater 49 integrated into it. It comprises a glow plug 51 inserted into a jacket tube 50 on whose surface the fuel vapors 48 are homogenized and post-heated before reaching the exhaust gas stream.